or a suitable filter, transparent to visible light but sufficiently opaque to x-ray may be placed in the line of sight.

Since many electrical shocks prove fatal only because of failure to apply restorative treatment at once, it is imperative that all personnel concerned with the operation of an x-ray unit be familiar with the methods of artificial respiration and the aftertreatment of a revived person. This familiarity should be the result of actual training. Although a physician should be summoned at once, the restorative measures should be started immediately, since the chances of a successful outcome are greatly increased by appropriate procedures in the first few minutes after the shock.

3. Shielding Materials for Protection against X-rays and Gamma Rays

Singer, Wyckoff, and Day[5] have made careful measurements on the relative thicknesses of lead, concrete, and steel required for protection from a narrow beam of x-rays generated by potentials from 200 to 1400 kv. They found that for 1400 kv. the ratio of thickness of concrete to the thickness of lead to produce the same attenuation is 5.5, a relation that is strictly linear from 10 to 75 cm. of concrete. At 1000 kv. this ratio is 6.4 for a range of thickness of concrete from 10 to 65 cm., with small departure from linearity in the region between 10 and 20 cm. At 600 kv. this ratio has increased to 10 for a range of 10 to 50 cm. of concrete, and at 200 kv. the ratio is about 50 between 10 and 25 cm. of concrete.

The ratio of thickness of steel to thickness of lead was found to vary from about 13.5 for 200 kv. radiation to about 1.5 for 1400 kv. radiation.

For many purposes, lead is most suitable for use in screening x-rays. In some situations, however, it is more convenient and economical to use other materials, including the structural materials of the building itself. One of the most common is concrete, carefully compounded and poured to prevent formation of air spaces. It is usual to specify lead equivalence of such materials to indicate their relative efficiency as a screen. The protection coefficient, which is the ratio of the thickness of lead to the thickness of material that absorbs a given beam of radiation to the same extent, is more convenient for calculation. The lead equivalent for a material is the thickness of lead found by multiplying a given thickness of the material by its protection coefficient. Values for protection coefficients, taken from data by Kaye[6] and his associates, are given in Table 5.

When dealing with x-radiation generated at potentials above 200 kv., scattering of the radiation is appreciable. At about 500 kv. the scattered radiation has a hardness of about one half that voltage, and for 1000 kv. the value is one third. Therefore, in computing thicknesses of shielding material where scattered radiation may be involved, the absorption coefficients for x-rays of voltages corresponding to those for the scattered radiation must be used.

[5] G. Singer, H. O. Wyckoff, and F. H. Day, *J. Research Natl. Bur. Standards*, 38, 665 (1947).

[6] G. Kaye, W. Binks, and G. E. Bell, *Brit. J. Radiol.*, 11, 676 (1938).

TABLE 5

Protection Coefficients (with Reference to Lead) for Some Structural Materials

Building material	X-rays				Gamma rays
	150 kv.	200 kv.	300 kv.	400 kv.	
Iron	0.08	0.07	0.11	0.14	0.47
Concrete	0.013	0.014	0.026	0.033	0.14
Brick	0.0009	0.009	0.015	0.019	0.08

4. Shield of the X-ray Tube

The x-ray tube in all cases should be completely surrounded, except for the opening for the emergent beam, with protective material of adequate thickness to reduce the radiation to tolerance level or below at all points outside the beam likely to be occupied by personnel. There has been a decided tendency in recent years on the part of manufacturers to make this shield an integral part of the tube structure, or support. However, it is desirable to make certain that the screening is adequate in all such types of tubes. Table 6 shows minimum lead thicknesses required for shields for a few typical voltages applied to the x-ray tube. These values are only approximate to illustrate the nature of the problem. In any actual installation the effectiveness of the shield should be tested by measurements of the dosage in roentgens at appropriate locations in the vicinity of the tube. For safest operation, personnel should never remain unnecessarily in the vicinity of an x-ray tube in operation, even though measurements have shown that the shielding meets the usual requirements. In most industrial applications there is no reason for anyone to be near the x-ray tube during an exposure.

TABLE 6

Approximate Lead Thickness Required to Protect Individuals from X-rays Generated by Various Voltages

X-rays generated by peak voltages not in excess of (kv.)	Minimum required thickness of lead barrier (mm.)	X-rays generated by peak voltages not in excess of (kv.)	Minimum required thickness of lead barrier (mm.)
75	1.0	400	15.0
100	1.5	500	22.0
125	2.0	600	34.0
150	2.5	800	40.0
175	3.0	1000	80.0
200	4.0	2000	175.0
225	5.0	5000	290.0
300	9.0		